

SEVENTY-SEVENTH

ANNUAL REPORT

OF THE

DIRECTOR

OF

THE ASTRONOMICAL OBSERVATORY

OF

HARVARD COLLEGE

FOR THE YEAR ENDING SEPTEMBER 30, 1922

BY

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THE OBSERVATORY

TO THE PRESIDENT OF THE UNIVERSITY: —

SIR, — A sufficient summary of the progress of work at the Astronomical Observatory for the past year can be made by stating briefly some of the results obtained at Harvard on major problems of astronomical research. It will appear below that increasing emphasis is placed on the interpretation of the large amounts of data accumulated at present and in the past at the Harvard Observatory. Many of the researches described below are based entirely on the collection of photographs made in Cambridge and Peru during the last thirty-five years.

1. *Globular Clusters.* Studies of star clusters have led in recent years to far-reaching conclusions concerning the extent and structure of the stellar system. More than twenty-five years ago Professor Bailey began his investigations here of variable stars in globular clusters. Various types of work on these objects were later taken up at Mount Wilson and elsewhere, and now globular star clusters, and the variable stars of the Cepheid class which are numerous within them, are considered the most useful objects in the sky for the study of great distances. With the return of Professor Bailey to Arequipa in March of this year, active observation on globular clusters was again started, using mainly the 24-inch Bruce refractor — a very powerful instrument for the photography of faint stars. Many new variable stars have been found during the year in or near the southern globular clusters, and several series of photographs have been made in order to permit the investigation of the light curves of their Cepheid variables.

A new determination of the distances of all globular clusters is being based on angular diameters and integrated apparent magnitudes, as derived from photographs already existing in the Harvard collection. Several new globular clusters have been studied on Harvard photographs; among them is a faint and very distant system, N. G. C. 2419, in the constellation Lynx, which appears to increase appreciably the dimensions heretofore assigned to the stellar system. The greatest astronomical length yet measured is the distance of 350,000 light years separating the two globular clusters N. G. C. 2419 and N. G. C. 6715 — a value determined by the writer and published recently in Harvard Bulletin 776.

2. *Nebulae.* The Bruce photographic telescope at Arequipa has now to its credit the discovery of more than one-fourth of all the nebulae known. From photographic plates made with this telescope, about 3,000 nebulae were discovered some years ago by Professor Bailey, Dr. Stuart, and Mr. Frost. During the past summer more than 2,000 new nebulae have been found on Bruce photographs by Mr. Menzel, who spent some months as an assistant in the Observatory. The new nebulae are mostly in the southern sky, and with few exceptions appear to belong to the spiral family (which includes spindles and globular nebulae), although but a small number show the typical spiral arms. A projected study of the distribution of the spiral nebulae should assist materially in the determination of the relation of spirals to the galactic system.

Professor Bailey has given some attention to the photography of the large diffuse nebulosities of the southern Milky Way during the past summer. Estimates of the distance of the dark nebulosities in Taurus and Scorpio have been made by the writer as an incidental result in the study of the distribution of brighter stars. Mr. Menzel has found five new nebulae of the planetary type.

3. *Magellanic Clouds.* Two results of some significance have been derived during the past year from the studies at Harvard of the Magellanic Clouds. First, among the hundreds of variable stars in the Small Magellanic Cloud, the writer found several with periods of less than one day, thus affording a basis for the direct extension of the period-luminosity law of Cepheid variation; this result is of much importance in establishing the photometric method of measuring the distances of the globular clusters and the dimensions of the galactic system. Second, the distance of the Large Magellanic Cloud was found, from the measurement of five globular clusters discovered within its limits, to be somewhat in excess of one hundred thousand light years.

A continuation of the study of the Magellanic Clouds will yield absolute magnitudes of several kinds of peculiar giant stars. It is already evident that many stars in the Large Magellanic Cloud exceed the Sun in brightness by ten thousand times.

4. *Spectral Classification.* The eighth volume of the Henry Draper Catalogue of stellar spectra is now in press. The ninth and last volume will be printed during the coming year, the expense of publication being generously assumed by Mrs. James R. Jewett, who is a member of the Visiting Committee of the Observatory.

It has been decided to continue the spectral classification of faint stars, paying particular attention to the rich Milky Way

regions which are of most interest to various investigators of the structure of the sidereal universe. During the past summer Miss Cannon spent several months at Arequipa, where she made plates specially for the continuation of this work. She also photographed many objects of peculiar spectral class, and with the 13-inch Boyden telescope assisted in the observational work on the spectrophotometric parallaxes of bright southern stars.

5. *Long Period Variable Stars.* As in past years, the Harvard Observatory has been the center for the visual study of variable stars of long period. During the year about 25,000 estimates of magnitude have been received here and discussed by Mr. Campbell. The observers are largely amateurs, and are widely distributed on all continents. Between three and four hundred stars are followed systematically by seventy observers. The American Association of Variable Star Observers carries on an important part in this work.

A satisfactory explanation of the cause of variation has not yet been found for long-period variables, but the material now available at Harvard permits the derivation of significant statistical results concerning the distribution, spectral type, length of period, magnitude of variation, and form of light curve, and aids in the correlation of these properties with motion and absolute brightness.

To perpetuate its organization for work on long-period variables, the American Association of Variable Star Observers is now endeavoring to raise a fund as a memorial to the former Director of the Harvard Observatory, Professor E. C. Pickering, under whose guidance the Association was developed. It is proposed to operate this memorial fund in connection with the Harvard College Observatory.

6. *Cepheid Variable Stars.* Because of the fundamental part played by Cepheid variables in measuring great distances, much attention has been given to them at Harvard during the past year. Several have been discovered by Professor Bailey and Miss Woods. Miss Walker has determined the photographic light curve of Y Sagittarii, a bright Cepheid suspected of unusual variation. The periods of a few cluster-type Cepheids, both in the Magellanic Clouds and in or near globular clusters, have been determined. A study by the writer of the motion and absolute magnitude of the cluster-type Cepheid RZ Cephei shows that this faint variable has the highest known velocity yet found for any star — about 1,100 kilometers a second.

An analysis of available data on proper motions and radial

velocities for cluster-type Cepheids of the galactic system has brought out the remarkable fact that these stars appear to be moving with a high velocity to a southern part of the Milky Way. It is suggested that stars of this kind in the vicinity of the Sun have had a common origin in globular clusters or some other non-galactic system. The systematic motion of these variables is of the same order of magnitude as that found at Flagstaff for globular clusters.

7. *Binary Stars.* On account of their importance in studies of stellar evolution, systematic investigations of eclipsing binaries are maintained at Harvard, in some problems coöperating with the Princeton Observatory. Mr. Campbell and Miss Woods have made visual and photographic observations, respectively, and Mrs. Shapley has carried on the necessary orbital computations. Miss Maury has continued her investigations of spectroscopic binaries, using not only the great store of spectrum plates made in the past with Harvard telescopes, but also several new series of photographs made at Arequipa during the past summer with the Boyden telescope.

8. *Planetary Observations.* As in the past, Professor William H. Pickering, at the Mandeville Station of the Harvard Observatory, has observed the planets and the Moon. Special attention was paid to the atmospheric phenomena on Mars during the favorable opposition of 1922. Professor King has continued his photometric observations, determining both photovisual and photographic magnitudes of the planets. He has also developed an ingenious method for obtaining the brightness of different portions of the Moon's surface, and has made quantitative measures of "earthlight."

9. *Stellar Distances.* Knowledge of the structure of the local star system depends primarily on determination of the distances of the stars. Considerable progress has been made at Harvard in measuring stellar parallax from spectrum plates, particularly of the southern stars of Classes G, K, and M. Two circulars have been published on this subject. It appears that the parallaxes of several thousand stars can be determined from plates already existing in the Harvard collection.

10. *Stellar Statistics.* The study of the distribution of stars of different spectral classes and magnitudes, using the material contained in the Henry Draper Catalogue, has received special attention. Three problems have been studied: first, the structure of the nearer parts of the Milky Way; second, the relation of spectral

Classes B and A to the local cloud; and third, the relative frequencies of the various spectral classes down to magnitude 8.25.

By the death of Miss Leavitt on December 12, 1921, the Observatory lost an investigator of the highest value. She had obtained a comprehensive experience in photographic photometry, and had developed a clear appreciation of the difficulties involved in the theory and practice of this important research. Her work on standard magnitude sequences was nearly concluded at the time of her death, but she had hardly begun work on her extensive program of photographic measures of variable stars.

In the foregoing summary no mention has been made of Miss Leavitt's work on standard photometry, of the progress with the 60-inch reflector, of determinations of proper motion, of the discovery of two new stars by Miss Cannon and Miss Woods, or of the study of irregular variable stars by Mr. M. F. Jordan and others. Nor can space be taken more than to mention the change in the character of the Harvard Bulletins, which permits the rapid and economical publication of the Observatory's results; the rearrangement and cataloguing of the library; the Observatory's part in the first regular meeting of the International Astronomical Union at Rome, attended by the writer, where members of the Observatory staff were elected to eleven positions on the twenty-six international commissions. The public interest in the Open Nights for visitors, and in the popular lectures at the Observatory, emphasizes the need of a suitable assembly room or building on the Observatory grounds. The demand for tickets of admission continues to exceed the possibilities of accommodation.

The work of the Observatory is, to some extent, indicated in the bibliography of its publications during the year. In addition to articles published in *Popular Astronomy*, *Proceedings of the National Academy of Sciences*, *Nature*, and other scientific journals, more than eighty scientific papers or notes by members of the staff have been printed in the official publications of the Observatory. The following list contains the titles of the papers appearing as Harvard Circulars, and a partial list of those appearing in the Bulletins.

- H. C. 227. Variable Stars. Predicted Maxima and Minima in 1922, by Leon Campbell.
- H. C. 228. The Distances of Fifty Stars Determined from Objective Prism Spectra, by Harlow Shapley and Bertil Lindblad.
- H. C. 229. The Local System and Stars of Class A, by Harlow Shapley and Annie J. Cannon.

- H. C. 230. Spectral Class and Magnitude in Harvard Standard Regions, by Henrietta S. Leavitt.
- H. C. 231. Stars having Peculiar Spectra. Eight New Variable Stars, by Annie J. Cannon.
- H. C. 232. The Distances of 87 Bright Stars of Class K, by Harlow Shapley and Martha B. Shapley.
- H. C. 233. The Orbit of the Spectroscopic Binary ζ Centauri, by Antonia C. Maury.
- H. C. 234. Photographic Work at Arequipa with the Bruce 24-inch Refractor. N. G. C. 3201, by Solon I. Bailey.
- H. C. 235. Observed Maxima and Minima of Variable Stars for 1921, by Leon Campbell.
- H. C. 236. The Variations in Light and Color of Y Sagittarii, by Harlow Shapley and Arville D. Walker.
- H. C. 237. Notes Bearing on the Distances of Clusters, by Harlow Shapley.
- H. C. 238. Light Curve and Orbit of a New Eclipsing Binary, H. V. 3622, by Ida E. Woods and Martha B. Shapley.
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- H. B. 760. Nova Puppis (Miss Woods).
- H. B. 761. A Fourth Variable of R Coronae Type (Campbell, Miss Cannon). Dimensions of Messier 3 (Shapley).
- H. B. 762. New Period for U Cephei (Campbell).
- H. B. 763. Note on the Velocity of Light (Shapley). Parallax of Messier 5 (Shapley).
- H. B. 764. Giant Stars Near the Pleiades (Shapley). New Variable in N. G. C. 6541 (Miss Woods). Spectral Classification of Faint Pleiades (Miss Cannon, Shapley).
- H. B. 765. The Absolute Magnitude of Cluster Type Variables (Shapley). Two Irregular Variables of Class K (Jordan). W Ursae Majoris (Campbell). New Cluster Type Variable in Small Magellanic Cloud (Shapley).
- H. B. 766. Eros and Palma (Miss Harwood).
- H. B. 767. Note on Ionized Calcium in β Aurigae (Shapley, Miss Maury). Variable Star of the W Cephei Type (Miss Leland).
- H. B. 769. Note on Red Dwarf Stars (Shapley, Miss Wells).
- H. B. 771. Abbreviation of Names of Constellations.
- H. B. 772. Variable Dwarf Star (Miss Wells).
- H. B. 773. Two Thousand New Nebulae (Menzel). Nova Scorpii 1922 (Miss Cannon). Star of High Velocity (Shapley).
- H. B. 774. New Eclipsing Variable Star (Miss Woods). Asteroids (Bailey). Star with Variable Bright Lines (Shapley, Jordan).
- H. B. 775. Group of New Globular Clusters (Menzel, Shapley). Approximate Distance and Dimensions of Large Magellanic Cloud (Shapley). Iris (Miss Harwood, Campbell).

HARLOW SHAPLEY, *Director.*